The influence of weather conditions on road safety

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An assessment of the effect of precipitation and temperature

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Summary

The annual number of road crash casualties fluctuates due to chance, mobility changes, changes in road safety measures, and other influencing factors, such as weather conditions. In order to better understand these fluctuations in road crash casualties, and potentially attribute them to changes in road safety measures or implementations, it is necessary to know how every factor relates to the changes in the number of crashes and casualties. The influence of changes in extreme weather conditions is often identified as a cause of fluctuations in road safety and the resulting numbers of crashes and casualties (see *e.g*. SWOV Fact sheet *The influence of weather on road safety*). Understanding the influence of the weather on these fluctuations is necessary when the aim is to reliably estimate the effects of safety measures. Furthermore, it may be possible to develop or enhance specific safety policies to help counter adverse effects of weather conditions on road safety.

The topic of the influence of weather conditions on road safety has resulted in many studies published in international journals and technical reports, a number of which are reviewed in the SWOV fact sheet *The influence of weather on road safety*. There is one problem in applying the results obtained from studies performed in other countries than the Netherlands to the Dutch road safety situation: the general climate in other countries can have an impact on how road users, legislators and road authorities react to (changes in) weather conditions. In mountain areas or in Nordic countries road authorities and drivers are better prepared for snow than, for instance, in the Netherlands. Differences in the mix of modes of transport could also be a factor: the role of bicycles and pedestrians in the Netherlands may be quite different from that in other countries. These factors may also affect the impact weather conditions have on road safety. Therefore, the available literature can mainly be used for guidance on the methodology on how to measure the effects of weather conditions on road safety in the Netherlands. Without modifications the results cannot easily be applied to Dutch circumstances.

The effects of weather conditions on road safety can be studied using different approaches. It is to be expected that weather conditions influence both road travel and the risk of road travel. One approach towards analysis of the effects of weather conditions on road safety is to analyse both effects separately and to combine these effects to obtain a general effect. An advantage of this approach is that the effects of weather conditions are decomposed into separate effects of mobility and risk, which may be interpreted separately. A disadvantage of this approach is that it requires information on travel under different weather conditions, or it must be assumed that travel is not affected by weather conditions.

Very limited information on travel under different weather conditions is available in the Netherlands, as this requires to match both travel data and weather data. In addition, it appears reasonable to assume that for many modes of transport the distance travelled is usually affected by weather conditions. Therefore, this report focuses on an analysis of the aggregate,

accumulated effect of weather conditions on the number of road crashes and injuries. This approach has the advantage of being applicable to most modes of transport because it makes no assumptions on how weather conditions affect mobility (distance travelled). It has however the disadvantage of its inability to determine the separate effects of weather conditions on mobility and risk.

Based of the experiences published by Eisenberg (2004), it was decided to analyse data at the daily and national aggregation level. Data for this level is available for the Netherlands.

One analysis was performed relating the daily aggregated weather conditions to daily aggregated travel and road casualty data. The results indicate that it is mostly non-professional travel (determined by reported trip motive) that is affected by weather conditions. Furthermore, but to a lesser extent, professional travel by weather sensitive travel modes, such as bicycle and moped, appear to be influenced by weather conditions.

Further analysis was conducted analysing the effects on the number of casualties in the Netherlands of the duration of precipitation, which the first analysis identified as an important factor. An approximate model was developed for this purpose. The model is based on the daily numbers of casualties under both dry and wet weather conditions (which are modelled simultaneously) and is used to determine the effects of precipitation under various combinations of conditions, including the length of the period considered (longest period 1987-2007), season, road user type and crash opponent type. This approach allows to reliably estimate the relative effect of precipitation on road safety.

The main benefit of this approach is that it relates 'precipitation crashes and casualties to the duration of the precipitation and 'dry crashes and casualties to the duration of the dry spells. Models that relate the total number of crashes or casualties to, for example, the amount of precipitation, cannot determine whether more crashes coinciding with more precipitation are in fact crashes caused by that precipitation. This issue becomes even more important when rarer weather phenomena than precipitation are studied. Even wet weather conditions occur only about 7% of the time in the Netherlands. Care should be taken in using an explanatory variable for the entire period which is not relevant for 93% of the time.

The method presented in this report can only be used when the relevant weather conditions can be determined for the casualty data. The weather condition also has to be dichotomous; it has to be either present or absent. In practice this limits the applicability of this approach for determining the effect of precipitation.

Two important tendencies in results can be distinguished for road safety in the Netherlands: the effects are different for different levels of crash severity and the effects are different for vulnerable transport modes and less vulnerable transport modes. Furthermore, it appears that in the Netherlands the impact of precipitation is more severe during the winter months than in other periods (snow and ice are sufficiently rare in the Netherlands to tentatively eliminate snow as an explanation). Apart from seasonal differences there is some indication that the effect of precipitation on the number of fatalities decreases over the years.

Finally, it should be mentioned that the results found in this study do not easily translate into potential road safety measures designed to limit the adverse consequences of weather. There is no clear aspect on which attention can be focussed.

Contents

1. Introduction

The annual number of road crashes and crash casualties fluctuates due to chance, mobility changes, safety measures and other influencing factors such as the weather. In order to understand these fluctuations, and potentially attribute them to safety measures, it is necessary to know how every factor relates to the changes in the number of casualties. Changes in weather conditions are considered a cause of fluctuations in road safety because of their influence on the number of road crash casualties and travel (see for example SWOV Fact sheet *The influence of weather on road safety*). Understanding the relation of the weather with these fluctuations is necessary when the aim is to reliably estimate the effects of safety measure. Also, it may be possible to develop specific safety policies that are related to weather conditions. Therefore SWOV is conducting research on the influence of weather conditions on road safety.

1.1. A qualitative description of the relation between weather and road safety

Reflected in the results of many studies into this subject (see also SWOV Fact sheet *The influence of weather on road safety*), it is commonly believed that weather conditions may have an influence on road safety. In fact, weather conditions are believed to influence various aspects that can affect road safety:

1. the decision whether or not to travel;
2. the choice of transport mode;
3. visibility of the road and other road users (for instance reflection of the sunlight by the wet road surface);
4. vehicle contact with the road (ability to brake and control the vehicle);
5. behavioural changes such as more cautious driving.

1.1.1. *The decision to travel*

There are two ways in which weather conditions can influence the decision to travel:

- not starting a trip at all;
- delaying or suspending a trip (for a brief period, for instance due to heavy rainfall).

The first category of decisions will mostly be made with respect to discretionary travel, as inferred from the non-work related trips in the Dutch travel survey (see *Section 3*). The second category is commonly observed in practice, as motorcyclists, mopeds, bicyclists or pedestrians take shelter from heavy rainfall or other adverse weather conditions. To a lesser extent, however, this also appears to be done by drivers of other vehicles.

1.1.2. *The choice of transport mode*

The choice of a different transport mode will be most frequent for journeys that in fair weather conditions have been by motorcycle, moped or bicycle. During adverse weather, travellers may switch from these modes of transport to others, e.g. car or public transport. Beautiful weather, on the other hand, may have the opposite effect and result in an increase in the use of transport modes suitable for fair weather. To some extent such an effect can be observed in the analysis of the effect of temperature on reported travel distances in *Section 3*. The choice for walking as a transport mode may also be a result of weather conditions, but it is not be clear how or why the choice is made: cyclists switching to public transport, for instance, also become pedestrians when they walk to the bus stop.

1.1.3. *Visibility of the road and other road users*

There are various effects of various weather conditions on visibility. Windscreen wipers can reduce the effect of rain; glasses and crash helmet visors, and the other hand can cause reduced vision when they get wet in the absence of wipers. Fog lamps have the particular purpose of improving visibility in foggy conditions. Reflection of the sun on a wet road surface is also mentioned in the literature as an adverse effect of weather conditions (e.g. Eisenberg, 2004).

1.1.4. *Vehicle contact with the road*

Wet or otherwise slippery roads influence the road grip capacity of vehicles, as most road users probably know from experience. Slippery roads may be caused by (excessive) rainfall, snow or (black) ice, or by wet leaves in the autumn. In addition, Eisenberg (2004) notices oil, accumulated on roads during dry periods, creating a thin film with rain water. The extent to which this happens probably also depends on the road surface type. Porous asphalt has been used to reduce the risk of aquaplaning while at the same time improving the visibility of pavement markings (Tromp, 1993).

1.1.5. *Behavioural changes such as more careful driving*

Changes in driver behaviour have been noted in the literature. Examples are changes of speed and following distance during times of rain (Edwards, 2000; Hogema, 1996). In response to a perceived increase in risk, traffic adapts lower speeds and increased following distances. However, this compensating for the increased risk is insufficient and higher collision rates are still evident during times of rain (Edwards, 2000; Andrey & Yagar, 1993; SWOV Fact sheet *The influence of weather on road safety*). Driver behaviour on porous asphalt, however, is thought to counterbalance the increased road contact since traffic speeds are not reduced as they would have been on conventional asphalt (Tromp, 1993).

1.2. **The relation between weather and road safety as a policy issue**

Unfortunately, it is not possible to influence the weather. Knowing the relation between weather and road safety, therefore, can only improve road safety when this knowledge can be used to influence behaviour during adverse weather or to improve vehicle or road design.

Quantitative knowledge about the relation between weather and road safety can be used in three ways:

1. When modelling safety data (e.g. the annual number of fatalities), this data should be corrected for weather influences,
2. Once it is known that specific weather conditions increase the crash rate, specific measures that compensate for these conditions can be

considered (for instance dynamic adaptation of speed limits, conditional driving permits for inexperienced drivers, etc.),

3. The effect of climate changes can be anticipated to formulate long term traffic and transport policies.

1.2.1. *Modelling road safety data*

The annual number of crashes, fatalities (or seriously injured) fluctuates due to chance and due to many influencing factors. Examples of these factors are changes in road safety measures, changes in (excessive) speeding behaviour, fluctuations in the number of inexperienced drivers, as well as changes in weather conditions. When the exact influence of such factors is not known quantitatively, this gives rise to misestimation in models.

1.2.2. *Weather related road safety policies*

Once the specific relation between weather conditions and road safety is known, safety policy specific for certain weather conditions can be considered. Especially when certain combinations of circumstances, like for example the combination of rain and darkness, strongly increase the crash rate, specific measures may be called for. Although it is difficult to estimate the impact of such policies in advance, it could be argued that this possibility justifies further research of this type.

1.2.3. *Long term policy based on the anticipation of climate change*

Weather conditions may also have a long term effect on road safety as life and economic patterns may be influenced by long term changes in weather conditions. Such changes are better considered within a climatological context, see KiM (*2008*), and are thus not covered in this report.

1.3. **Methods used to quantify the relation between weather and road safety**

In addition to qualitative approaches as taken by, for instance, Bos (2001), two approaches can be taken to quantify the effect of weather on traffic safety. The first approach is to examine the relation between weather conditions and the number of casualties in the same period. In this document, this approach will be called the aggregate approach. The second approach is to study the effect of weather conditions on mobility, and subsequently the effect of weather conditions on the crash rate (crashes under certain weather conditions given a certain mobility).

SWOV considers the individual choice of whether or not to travel to be outside the field of road safety research. Regardless of the size of the influence on the number of fatalities, mobility itself is seen as a given consequence of economical and social activities. Safety research is aimed at achieving safe mobility outcomes, as far as SWOV is concerned.

In Bijleveld (2008, Chapter 7) a time series model is developed which is used to estimate the traffic volume under wet and dry weather conditions and the relative crash rate under wet weather conditions compared to dry weather conditions for each day. This is done using precipitation duration data for 10 weather stations distributed over the Netherlands. The method accounts for the fact that on some days the weather pattern obtained from these weather stations is quite inhomogeneous, in which case the travel volume under wet and dry weather conditions is hard to determine.

Currently, due to lack of data regarding the effects of weather conditions on exposure, the mobility based approach is very difficult if not impossible to properly perform for any mode of transport except for passenger cars, which is used in Bijleveld (2008, Chapter 7). The direct effects of weather conditions on travel turn out to be limited for that group (see *Section 3*). The mobility based approach thus currently covers only a segment of road safety, but could, however, offer more detailed insight in the effect of weather conditions on road safety, and may therefore be more suited for identifying options for improving road safety under specific weather conditions.

This report focuses on the study of aggregate effect of weather conditions on road safety; the empirical relation between weather conditions and the number of casualties in general is studied. Given that mobility data is not available for different weather conditions, the mobility based approach is far more complicated than the aggregate approach used in this report. Combinations of changes in mobility levels and changes in risk due to weather conditions are beyond analysis at this point; furthermore, this level of detail may not provide any additional information. By evaluating the empirical relation of weather and collision outcomes, a better understanding of the overall effect of weather on traffic safety will be obtained, and will possibly suggest which direction future research should take.

The topic of the effect of weather conditions has resulted in many studies published in international journals, as can be concluded from reviews like the SWOV fact sheet *The influence of weather on road safety*. Using results obtained from studies performed in other countries has one drawback: the general climate may have an impact on how individuals (as well as legislators and road authorities) react to (changes in) weather conditions. In mountain areas or in Nordic countries the population is better prepared for snow than, for instance, the population in the Netherlands. Furthermore, the mix of transport modes may stand in the way of comparability: the role of bicycles and pedestrians in traffic in the Netherlands may be quite different from that in other countries. Therefore, the available literature is mostly useful for guidance on the methodology that can be used to measure the effects of weather conditions on road safety in the Netherlands. The results with respect to the actual influence of weather conditions on road safety cannot be applied to Dutch circumstances without modifications.

1.4. Data used

The analyses in this report are based on Dutch crash data since 1987. The data are taken from police records, which specify the weather conditions during the crash. No correction has been made for underreporting, which is assumed not to be correlated with weather conditions.
The mobility data used is taken from the annual Dutch MON and OVG surveys. Weather data was obtained from the Royal Netherlands Meteorological Institute, KNMI (www.knmi.nl).

2. Aggregate models: annual, monthly, daily or hourly data?

When the relation between road safety and weather conditions is to be studied, it is important to consider aggregation effects in weather related studies. Eisenberg (2004, p. 637), for instance, found that "in a typical state-month pair in the US from 1975 to 2000, increased precipitation is associated with reduced fatal traffic crashes. More precisely, an additional 10 cm of rain in a state-month is associated with a 3.7% decrease in the fatal crash rate". These results were found using data aggregated to the monthly level. Eisenberg continues, later describing day level data aggregation: "First, when the regression analysis is conducted with the state-day, rather than the state-month, as the unit of observation, the association between precipitation and fatal crashes[1] is estimated to be positive and significant, as in the literature." (Eisenberg, 2004, p. 637). Both remarks explicate the importance of the aggregation level. It is clear from Eisenberg's remarks that annual or monthly data may not be suitable for measuring the *immediate* effect of rainfall on road safety. Given Eisenberg's remarks, the possibilities of an aggregation level under the daily level should be considered.

Andrey & Yagar (1993) compare crash periods with and without rain in Calgary and Edmonton, Canada. They matched a period with rain to a period matching in clock time and day of the week one week apart, but essentially without rain (Many other studies use calendar days, not general periods). Andrey & Yagar (1993) used data under the daily aggregation level, distinguishing time with rainfall and time after rainfall. One of their findings that influenced the approach in the current study is that these authors found that risk levels returned to normal immediately:

> "Surprisingly, when rainfall ends, the accident risk is reduced to normal levels immediately, despite the fact that more than one-third of the accidents that occur in the first hour of the postevent periods take place on wet roads. This raises the question as to how much of the rain hazard is road friction and how much is visibility. The evidence presented here would suggest that drivers are able to compensate for wet road conditions, but that reduced visibility during rainfall results in increased travel risk." (Andrey & Yagar, 1993, p. 468).

One of the problems faced in this study is that crash data is not as reliably detailed as one might believe from the records. In the Netherlands, crashes – even very serious ones – according to crash data, tend to occur at 'rounded time points', as can be seen in *Figure 1*.

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[1] Note that Eisenberg used all fatal crashes per day, irrespective of weather conditions.

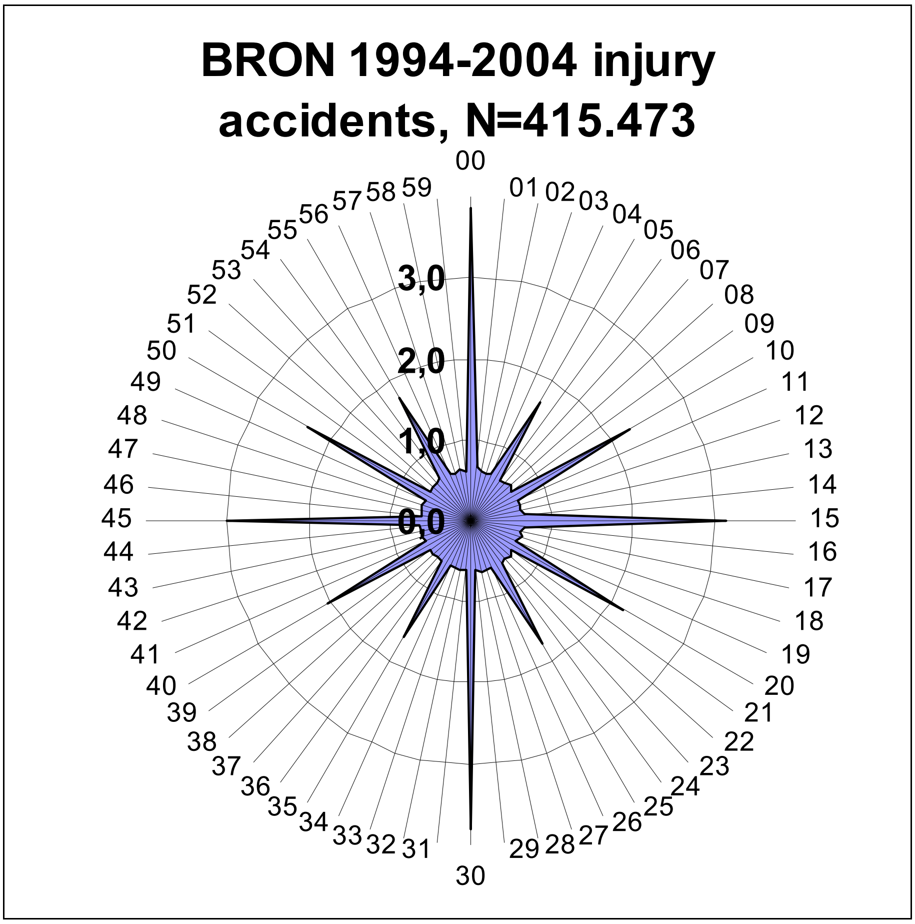

Figure 1: *Distribution of the minute in which an injury crash occurred according to its police record. Note: at the hour (zero minutes) recorded eight times more than at one minute past the hour.*

Figure 1 shows the distribution of the minutes that injury crashes occur according to police records. It is obvious that the minute readings of crash times are clustered. This is probably the case because crash times are recorded mostly from recollection rather than from accurate measurement. As a result, road users are more likely to report that the crash occurred at 11 o'clock than 10:56. Similar effects appear to influence the half-hour mark, and so on. The problem this issue presents is that it will be very difficult to match such data with some of the detailed (hourly or better) weather station data. The geographic area for which the weather station measurements are representative will present a similar bias to that in the collision reporting example above. Although matching is probably accurate enough to match temperature readings from weather stations with crash data, it is probably difficult to sufficiently rely on matching rainfall data readings from (local) weather stations with crash data. Considering these issues, and the results found by Eisenberg (2004), at this point it is chosen to restrict the aggregation level to the daily level.

The analysis presented in this report relies on the police registration of the weather conditions. Offermans (2006) verified this information in a sample of crashes and found this information reasonably reliable when compared to satellite data; 80% of police records that included weather conditions had weather data consistent with the satellite data.

3. Preliminary analysis of the effects of weather conditions on the distance travelled, and crash indicators

This section presents a preliminary analysis of the effects of temperature (mean, minimum and maximum) and precipitation (amount in mm and duration) on the kilometres travelled for a number of transport modes. The data used has been taken from the Dutch travel surveys OVG and MON. Beforehand, it should be noted that a small error is introduced due to the fact that daily weather data is recorded in universal standard time (UTC) date, while travel and crash time data is recorded in Middle European (winter/summer) time. All crash time data in this study has been trivially recoded into UTC times. This recoding, however, is not trivial for Dutch mobility data but due to the low volumes during the time discrepancy, and the consistent time period, bias from this time difference is deemed to be minor. Additional data issues regarding the collision reports and weather monitoring as discussed in *Section 2* are also not expected to have a significant effect on the model results.

3.1. Estimation details

It is not assumed that any weather variable has a linear (or otherwise predetermined) relation with travel or casualty data. It is however assumed that, in case of a positive relation, an increase in a weather variable is associated with an increase in a travel variable (and a *decrease* in case of a negative relation).

Therefore, for each combination, a rank-correlation coefficient and its significance is computed. A rank correlation is a measure of the correspondence between the order of two variables: an increase (or decrease) in one variable – not necessarily always the same in absolute magnitude – is on average associated with an increase (or decrease) in another variable – not necessarily always the same in absolute magnitude. This approach allows for nonlinear but monotone relationships between variables. This particularly allows identification of relations where, for instance, temperature has a limited effect when it is cold, while it may have a large effect when the temperature exceeds a certain threshold. This approach, however, will not identify convex or concave relations, in which the level of the travel data variable is the same in the low values of the weather variable as in the high values of the weather variable. A further limitation is that the approach only allows comparison of two variables at a time.

The rank-correlation coefficient used in this analysis is Kendal's tau (tau not related to the τ used elsewhere in this report), as it is best comparable to the traditional correlation coefficient among alternative measures.

Only significant rank correlations are listed. Furthermore, it is emphasised that the results can only indicate an empirical relation, not a causal relation. One should consider the possibility of an alternative explanation (or *explanations*) that coincides with an explanatory variable used in this analysis.

In all cases analysed, the amount of travel in kilometres: total, professional and non-professional, the number of casualties (KSI) and fatalities has been further disaggregated for transport mode on the one hand, and has been correlated with the average, minimum and maximum temperature, and amount and duration of precipitation on the other hand. In case of a temperature analysis, dry and wet weather conditions have also been distinguished.

3.2. Estimation results

The results in *Table B.1* to *Table B.5* in *Appendix B* indicate that it is non-professional travel (determined by the motive reported) that is affected most by weather conditions, as indicated by the values found in the columns "Non-professional travel". In addition, but to a lesser extent, it is professional travel by sensitive transport modes that also seems to be influenced by weather conditions. Based on these results one should be careful about assuming travel to be proportionally distributed over time with and without precipitation, a weather condition which apparently affects travel. The almost complete insensitivity of car travel to both amount and duration of precipitation suggests that the approach taken in Bijleveld (2008, Chapter 7) is reasonable, for that transport mode.

In general it can be concluded that, apart from precipitation/rainfall which will be discussed more elaborately in the next section, it is quite probable that temperature also has an effect on road safety. A substantial number of significant rank correlations have been found, which exceed the effect the temperature may have had on mobility. This could result in the interpretation that the crash rate increases with temperature. Please note that this conclusion cannot be formally confirmed by this analysis. The effects on travel are more easily interpreted than the effects on traffic safety, as the effect on travel is also involved. Potentially less plausible alternative explanations based on effects on traffic volume cannot be excluded. The fact that the rank correlations based on the *maximum* temperature are somewhat larger (in magnitude) than the rank correlation based on the *minimum* temperature is quite interesting. This may indicate a 'summer' effect on travel habits. The fact that the rank correlations for motorcycles are even higher for casualty related indicators could be *tentatively* attributed to, for example, less experienced motorcyclists being more likely to travel on hot summer days, as this seems to have a stronger effect on casualties than on mobility. The current study design, and the fact that only rank correlations are used at this point to analyse the data, should suggest a more conservative interpretation. The nature of the analysis technique does not exclude the alternative explanation that the temperature only has an effect when it is *cold*. At a higher temperature, say at 20 degrees Celsius, the relation may not be very strong. Detailed analysis reveals that the rank correlations are least in winter and it could be interesting to investigate this issue further. However, the impression remains that under the influence of temperature, the amount of travel using the "weather sensitive transport modes" is positively related to temperature, non-professional travel is affected most, and that the related number of casualties is even more strongly related to temperature.

4. Analysis of the effects of precipitation on road safety

This section describes the method that is used to estimate the additional hazard of precipitation (in practice rainfall) on road safety. The method is designed to include all types of crashes or, as is chosen as the focus in this report, for all types of casualties, irrespective of traffic mode or road type. This means that some options available for some well-monitored highways cannot be used.

One of the major problems in comparing the effects of rainfall on road safety is correcting for the direct effects on travel due to rainfall: if all cyclists immediately take shelter when it starts to rain, there would be virtually no traffic by cyclists during rain. Even when fewer casualties are registered under wet conditions, it may still be far more dangerous. Therefore, careful consideration is needed as to precisely what effect is measured: the effect on crash rate or the aggregated effect. In other words, when it rains it may be much more dangerous, but as fewer people travel, fewer crashes actually occur. So from one perspective traffic is more dangerous, from the other it is safer. The approach taken in this report evaluates the aggregated effect, rather than the effect on crash rate.

The approach taken here closely resembles the ‘corrected wet pavement index’ (based on the ‘wet pavement index’ developed by the National Transportation Safety Board, 1980) as discussed by Brodsky & Hakkert (1988, p. 170). There the ratio of the proportion of wet road surface (also called pavement) crashes to the proportion of wet road surface time is studied. As there are numerous issues related to the estimation of wet road surface time (for instance assumptions on drying time after rainfall), in the present study 'wet road surface ' is replaced by 'wet conditions': this means that in fact the ratio of the proportion of wet crashes to the proportion of wet weather time is studied (that is, time with precipitation), although the actual implementation of the approach is somewhat different.

4.1. Estimation details

In this section an equation is derived that expresses the expected number of fatalities (seriously injured, minor injuries etc.) on a day that it rains during a fraction τ of the time. Although only the analysis of fatalities will be discussed, the theory and method are the same for the other severities considered.

Let t_r be the duration in hours with rain, and t_d be the duration of dry spells. The fraction of time it rains, τ, then equals

$$\tau = \frac{t_r}{t_r + t_d} \qquad (1)$$

Where, except when further exclusive weather conditions are considered, for daily analysis $t_r+t_d = 24$. Let $\tilde{N}_r$ be the expected number of fatalities during rainy hours, and $\tilde{N}_d$ be the expected number of fatalities during dry hours. Now, when the probability that it rains is independent from time of day or any other factor that might influence the probability of a fatality, we may assume that, on average, the number of fatalities (or any other kind of casualty) is proportional to the number of hours. However, the ratio of fatalities to duration may differ for rainy and dry conditions. Thus:

$$\tilde{\mathrm{N}}_\mathrm{d} = r \cdot t_d \text{, and } \tilde{\mathrm{N}}_\mathrm{r} = (1+\alpha) \cdot r \cdot t_r . \tag{2}$$

Here, it is assumed that during rain, the expected number of fatalities per hour is increased by a factor (1+α). When α is positive, the rainy hours indeed are expected to have more crashes, and in the case α is negative, the rainy hours are expected to have fewer crashes.

In our analysis, we calculate the ratio $f(\tau) = \tilde{N}_r/(\tilde{N}_d + \tilde{N}_r)$ as a function of τ. For τ=0, this ratio is expected to be 0 (no rain-fatalities), and for τ=1, the ratio is expected to be 1, as all crashes will occur during rain, because when τ=1, it rained all day (there were no days with 24 hours of rain in the data set). In general:

$$\mathrm{f}(\tau) = \frac{\tilde{N}_r}{\tilde{N}_r + \tilde{N}_d} = \frac{(1+\alpha)\cdot r \cdot t_r}{r \cdot t_d + (1+\alpha)\cdot r \cdot t_r} = \frac{(1+\alpha)\cdot t_r}{t_d + (1+\alpha)\cdot t_r} \tag{3}$$

Dividing numerator and denominator by (t_r+t_d), (t_r+t_d is non zero), and substitution of (1) in (3) and using the fraction of time with dry weather t_d / (t_r+t_d) = 1- τ yields:

$$\mathrm{f}(\tau) = \frac{(1+\alpha)\cdot \tau}{1-\tau+(1+\alpha)\cdot\tau} = \frac{(1+\alpha)\cdot\tau}{(1+\alpha\cdot\tau)} \tag{4}$$

4.2. Approximate likelihood model

From (4) it can be concluded that f(τ) depends on α and τ only. This section describes how α can be estimated from data.

In (2) the relations $\tilde{\mathrm{N}}_\mathrm{d} = r \times t_d$, and $\tilde{\mathrm{N}}_\mathrm{r} = (1+\alpha)\times r \times t_r$ are defined. For each available day, these relations link the observed data that is available: N_d, and N_r, the number of casulaties (fatalites for example) under dry (d) and wet (w) weather conditions to the time with rain t_r and dry weather t_d for which $\tilde{N}_d$ and,$\tilde{N}_r$ respectively are estimates. Although data about weather conditions is available from a number of weather stations distributed over the Netherlands, in this study the data of the Netherlands' main weather station in de Bilt is used. Bijleveld (2008, Chapter 7) uses data from 10 weather stations across the Netherlands to obtain more detailed results, but these are not essential for this analysis.

The observed quantities may be linked as follows:

$$N_d = t_d \cdot r + error_d$$
$$N_r = t_r \cdot r \cdot (1+\alpha) + error_r$$
(5)

The role of α in this equation is thus of most interest to road safety. It effectively determines how many relatively more crashes or casualties are to be expected when it is raining. Unless t_r or t_d is zero, (5) it bears information on the value of α.[2] From here an approach is taken which compares the relative number of casualties under dry and wet weather conditions with the fraction of time with rain. The idea is that, if wet weather conditions do not affect road safety, on average the relative number of wet weather casualties would be equal to the fraction of time with rain[3].

Based on (5), it is possible to estimate α from crash data for each individual day with both rainy and dry periods which are then statistically averaged. The methodology is based on maximum likelihood estimation and is presented in *Appendix B*.

4.3. Estimation results

A summary of the results of the analysis is given in *Appendix B*, *Table B.6* to *Table B.18*. A basic tendency found is that the factor α *increases* with diminishing severity. Thus, the number of fatalities appears to be less sensitive to the duration of precipitation than the number of in-patients, which in turn is less sensitive to the duration of precipitation than the number of slightly injured. By design, it is unlikely that this effect is caused by exposure effects: are more vulnerable road users – within one transport mode (vulnerable car passengers compared to less vulnerable car passengers) – more likely to defer travel when it rains? The exception to this rule appear to be pedestrians, for whom the factor for the number of fatalities, 1.13, (*Table B.6*) appears to be significantly larger than the factor for the number of slight injuries, 0.66 (*Table B.8*).

Comparing between transport modes, it is also interesting to see that the coefficients among vulnerable modes of transport are relatively low, and some are even negative: fatalities (*Table B.6*), hospitalised (*Table B.7*), and fatalities plus hospitalised (*Table B.9*). It is quite possible that this is in fact an exposure effect and that, although the crash rates are significantly higher, the reduced exposure results in fewer casualties. In autumn (*Table B.15*) and winter (*Table B.16*), however, these coefficients are larger than the average for the entire year (*Table B.10*). In general, it can be concluded that the coefficients appear to be larger during winter time than in the other periods. It would be interesting to compare these results with Andrey & Yagar's results (1993). These authors conclude that the adverse effects of rainfall may be related more to visual problems than to road friction: "The evidence presented here would suggest that drivers are able to compensate for wet road conditions, but that reduced visibility during rainfall results in increased travel risk." (Andrey & Yagar, 1993, p. 468). The fact that the coefficients are largest in winter may be related to the fact that the periods of darkness are longer in winter. Some studies appear to have modelled 'daylight' as an effect, but this is often done by using a variable `time of the day' rather than actual light conditions. Considering all casualties, no general tendency seems to occur over time when the first period (*Table B.11*) is

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[2] Obviously, there is no way to determine how much more dangerous traffic would have been under wet conditions on days on which it in fact did not rain.

[3] If the effect needs to be related to the relative risk under wet weather conditions, it should furthermore be assumed that travel is not influenced by rainfall. This assumption may not be tenable for all modes of transport.

compared to the last period (*Table B.12*). However, when focussing on the total number of fatalities (*Table B.18*), it appears that the coefficients decrease with time.

5. Conclusion

The topic of the effect of weather conditions on road safety has resulted in many studies published in international journals, as can be concluded from reviews like the SWOV fact sheet *The influence of weather on road safety*. One problem using results obtained from studies performed in other countries is that the general climate may have an impact on how road users react to (changes in) weather conditions. In mountain areas or in Nordic countries road agencies and drivers are much more prepared for snow than, for instance, in the Netherlands. This may also affect the mixture of transport modes: the role of bicycles and pedestrians in the Netherlands may be quite different from that in other countries. Therefore, the available literature is mostly useful as a guidance for the methodology used to measure the effects of weather conditions on road safety in the Netherlands, but results need to be adapted to conditions in the Netherlands.

In the present study an attempt is made to analyse the effects of weather conditions on road safety in the Netherlands, with some focus on precipitation. The approach taken in this study is to estimate the effect on road safety in general, not restricted to for instance highways, or towns, or areas for which reasonable data happen to be available. Although such an approach may give a better insight in the effects of weather conditions on road safety for those specific cases, it may not be clear how such results (towns, main roads) can be generalized to apply to the general road safety situation.

Based on the experiences published by Eisenberg (2004), who compared results obtained from studies at the daily and monthly aggregation level, it was decided not to analyse data at the aggregation level of month or years, but to limit research efforts to the level of individual days. This level coincides with easily available data for the Netherlands and is also comparable to other studies.

5.1. **Findings**

The results of the analysis of weather conditions indicate that it is non-professional travel that is affected most by weather conditions, in particular by precipitation. Furthermore, but to a lesser extent, professional travel by weather sensitive transport modes, such as bicycle and moped, also appears to be influenced by such weather conditions. Based on these results one should be careful to assume remaining travel to be proportionally distributed over time with and without precipitation, as apparently distance travelled is affected by precipitation. This means that without specific information on mobility (distance travelled) under different weather conditions, it will be impossible to even plausibly determine effects of weather conditions on mobility and crash rate. In addition, some effect of temperature on traffic volume is to be expected. Based on the analysis, it can be concluded that the amount of mobility is positively related to temperature, and that this is even stronger the case for the number of casualties in relation to temperature. Note that stronger means strength of association, and not necessarily that its value increases more when temperature increases more.

Using an approximate statistical model, further analysis is conducted analysing the effects of precipitation duration on the number of casualties in the Netherlands. The model is based on daily casualties counts both of killed and of killed or seriously injured for both dry and wet weather, which are modelled simultaneously.
Models that relate the total number of casualties to, for instance, the amount of precipitation can never determine that more crashes coinciding with more precipitation are in fact due to more crashes with precipitation occurring. It rains only about 7% of the time in the Netherlands. Care should be taken using an explanatory variable which is not relevant for 93% of the time. Although the approach taken in this report most likely is better suited for reliably estimating the effects of precipitation than approaches based only on general (casualty) counts, it can only be performed when the relevant weather conditions can be determined for the casualty data. This limits the applicability of this approach for determining the effect of precipitation.

Two important tendencies in results can be distinguished for road safety in the Netherlands: the effect is different for different levels of crash severity and this effect is different for vulnerable transport modes and less vulnerable transport modes. Furthermore, the impact of precipitation in the Netherlands appears to be more severe during the winter months than in other periods (snow and ice are rare in the Netherlands). Apart from seasonal differences, there is a slight possibility that the effect on the number of fatalities is decreasing with time. However, time series studies such as Bijleveld (2008, Chapter 7) are better suited for making such inferences. The results show that the number of fatalities almost doubles under precipitation, and that the number of killed or hospitalized more than doubles. The results also indicate that the effects in autumn and winter are larger than in spring an in summer.

It in interesting to note that in general precipitation has negative consequences, in the sense that more time with precipitation is related to more casualties. However, for some combinations of transportation this appears not to be the case, probably due to mobility effects.

It should be noted that the results are obtained using methods using daily data. Eisenberg (2004) found different results analysing at the monthly or daily level. It may be the case that data on an even more detailed level reveal other effects. However, it may not be feasible or worthwhile to perform a more detailed analysis, as due to data quality issues this not necessarily translates into more reliable results. A pilot study is required to determine to what extent this is true.

Finally, it should be mentioned that the results found in this study do not easily translate into potential road safety measures designed to limit the adverse consequences of weather.

5.2. Suggested further research

The suggestions in this section are inspired by both feasibility in terms of available data in the Netherlands and technical options, and assumed relevance for filling in the knowledge gap of the relation between traffic safety and weather conditions.

Data analysis in this report was limited to the daily aggregation level. Using hourly aggregated data at the national level is both expensive in terms of data costs and analysis efforts. It is suggested to first match hourly rainfall data from De Bilt to RAVU ambulance data and BRON crash data in the province of Utrecht, where De Bilt is located. Using both RAVU and BRON data may enhance the accuracy of crash times. This study may offer an indication of the benefits of using models based on hourly intervals, with localized weather data.

The research findings so far suggest the possibility of an interaction effect between light conditions and rainfall in relation to road safety. A dedicated study of this phenomenon may be important to determine whether for this reason alone further disaggregation is necessary.

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Appendix A A model for the number of crashes under both dry and wet weather conditions

In the following derivation the absolute times t_r, t_d and the crash rate r are replaced by the fraction of time dry τ_d, fraction of time with rain τ_r and a common crash rate component μ. Assuming an independent Poisson distribution for the number of crashes or casualties, (5) would yield a log-likelihood of

$$\begin{aligned}&\log likelihood = -\mu - \alpha\mu\tau + N_r \log\left[(1+\alpha)\mu\tau\right] + \\ &N_d \log\left[\mu(1-\tau)\right] - \log\left[N_r!\right] - \log\left[N_d!\right]\end{aligned} \tag{7.1}$$

for each day, including the parameter μ (which is of secondary importance for this analysis). The log-likelihood in (7.1) can be maximised for μ for each day (in terms of a generalised linear model: a dummy effect for each day, attributable to for instance differences in traffic volume between days. The dummy effect for the number of days in this analysis is, given the hardware implementation available, too large for GENMOD in SAS):

$$\underset{\mu}{\arg\max} \log likelihood = \frac{N_d + N_r}{1+\alpha\tau}$$

Which can be substituted into (7.1):

$$\begin{aligned}&\log likelihood = -N_d - N_r + N_r \log\left[\frac{(1+\alpha)(N_d+N_r)\tau}{1+\alpha\tau}\right] + \\ &N_d \log\left[-\frac{(N_d+N_r)(\tau-1)}{1+\alpha\tau}\right] - \log\left[N_r!\right] - \log\left[N_d!\right]\end{aligned} \tag{7.2}$$

Maximisation of (7.2) (technically called a profile likelihood) is used to determine the maximum likelihood estimate of α, and its confidence interval. The optimum value $\hat{\alpha}$ of (7.2) for one observation (for all observations finding the maximising value is preferably done numerically) can be determined analytically as well (note that this estimator is undefined when no dry weather crashes occurred ($N_d = 0$), or when it did not rain at all ($\tau = 0$)):

$$\hat{\alpha} = \underset{\alpha}{\arg\max}(7.2) = \frac{N_r - (N_d + N_r)\tau}{N_d\tau}. \tag{7.3}$$

Interestingly, this solution is equivalent to the corrected index by Brodsky & Hakkert (1988, p. 170). These authors define the excess crashes:

$$X = {(W - rT)}\big/{(1-r)}$$

where W is the number of *wet pavement* crashes (here the number of rain crashes is used because it is considered to be registered more reliable). Brodsky & Hakkert (1988) also consider the potential problem of the reliability of the determination of the duration of wet road surface, particularly as an exposure measure. In this study it is assumed that the match of rain duration with rain on the police record is more reliable than an estimate of wet road surface duration with wet road surface on the police record). In Brodsky & Hakkert (1988)' s notation T is the total number of crashes ($N_d + N_r$) and r is called the ratio of wet time, which is assumed[4] to be equal to τ. Brodsky & Hakkert (1988)' corrected index CI is now:

$$CI = W/(W-X) = \frac{\mathrm{N_r} - \mathrm{N_d}\,\tau - \mathrm{N_r}\,\tau}{\mathrm{N_d}\,\tau} = \alpha - 1 . \qquad (7.4)$$

There are some issues with the likelihood, which is in fact an approximation to the true likelihood of the model. First of all, all uncertainty is assumed to be in the distribution of the count. Unfortunately, it is not only the number of casualties that is subject to random error, it is also the fraction of time that is not accurately controllable. One problem is that the available data is rounded off, which implies some random error in the resultant data. But the most serious problem results from the fact that the data used is truly representative for only a small area close to the weather station in de Bilt. The dots in the left-hand panel of *Figure 2* are subject to vertical random fluctuation in the casualty counts, and to horizontal fluctuations due to the representativeness for the Netherlands of the weather conditions in de Bilt.

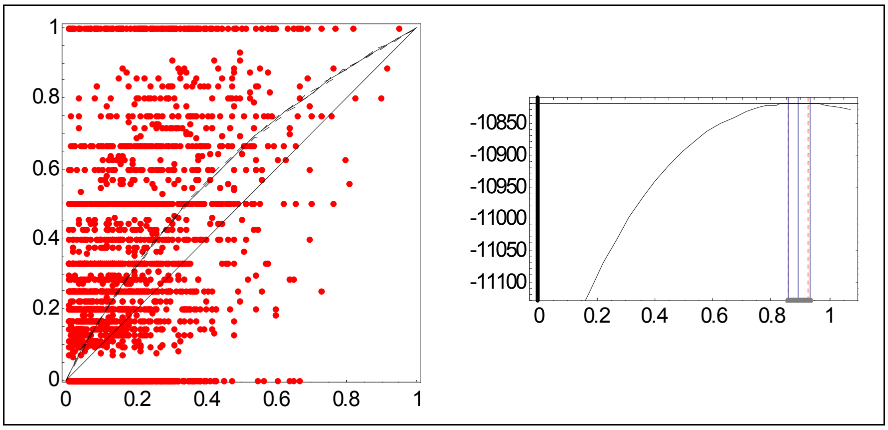

Figure 2. *Left hand panel: f(τ) for pedestrians injured in crashes with cars (all casualty types). Right hand panel: likelihood curve. Note that dots in the left hand panel denote days, but it is not indicated how many casualties are incurred on these days.*

Secondly, it is casualty counts that are analysed in this study while a Poisson distribution is assumed. At this moment, an alternative computational approach based on standard generalised linear models is not

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[4] It is not entirely clear whether the Brodsky and Hakkert mean 'ratio of wet time' in the sense of wet pavement time / dry pavement time, or, as indicated on top of page 170 of Brodsky and Hakkert (1988) in their equations , 'the proportion of wet pavement time', which would yield results equivalent to those found in this study.

feasible, as it does not allow for errors in variables. When final results are to be evaluated, it should be considered to use regional models and to use an errors-in-variables approach as for instance used in Bijleveld (2008, Chapter 7). However, the approach taken there is only applicable to a limited set of road safety variables. When further disaggregation is considered (either in terms of space: regional, or in time: hourly), it should be realised that the current approach only works when both dry and wet weather crashes occur. Beforehand one cannot assume that further disaggregation is very beneficial. Furthermore, it should be noted that this choice could also depend on the further direction of the research into the relation between weather conditions and traffic safety. In order to optimise research efforts, the approximate likelihood approach is upheld in this study. As a result, for the most part the confidence intervals given should not be assumed very accurate; however, these results should not be too unreliable.

Appendix B Relation between weather conditions and travel and crash statistics using rank correlations

When the relation between the number of casualties and for instance the average temperature is to be studied, it is important to consider the possibility that the relationship is not a linear relationship. In fact, the effect of a change in 10 degrees centigrade, from -10 degrees to 0 degrees may be different from the effect of a change from 20 degrees to 30 degrees. A graphical representation of the effect of temperature may reveal such a difference, but as many combinations will be considered in this study, graphically evaluating all relationships is not feasible.

For that reason a nonparametric correlation coefficient is used in this study, which may still identify the strength of such relations. To this end, Kendall's tau is selected, as its interpretation resembles the interpretation of the common correlation coefficient and is therefore relatively easily understood by the general reader.

In the following tables, an analysis is performed for all modes of transport labelled *All modes*, and for disaggregated categories labelled *Walking*; *Bicycle*; *Moped*, including light-mopeds; *Motorcycle*; *Car*; *Van* and *Public transport*. For each of these categories, unless precipitation effects are considered, a further distinction is made between dry days (following the Royal Netherlands meteorological institute defined as days with less than 0.1 mm precipitation) and wet days. This means that the effect of the average temperature is considered separately on both dry and wet days, while obviously, the effect of the duration of precipitation is not considered on dry days.

For each of these conditions, and for each day, the amount of travel according to OVG/MON Dutch mobility data is determined, and labelled *Travel distance*, this distance is disaggregated further into the amount of travel for professional purposes, labelled *Professional travel* and the amount of travel for non-professional purposes, labelled *Non-professional travel*. In addition, the number of fatalities for each mode of transport, labelled *Number of fatalities* and the number of fatalities plus the number of hospitalised casualties, labelled *Number of casualties* is obtained from police registered crash data BRON (AVV). From the KNMI (Royal Netherlands Meteorological Institute) website (www.knmi.nl), the average temperature for that day, the minimum temperature and the maximum temperature, the amount of precipitation (in mm) and the duration of precipitation (in 6 minute units) are obtained. Temperatures are measured in degrees Celsius. However, the nonparametric method used is insensitive to the unit of measurement. Likewise, if the common correlation coefficient was used, the choice of the unit of measurement would have no influence.

See Table B.1 for the rank correlations with the average temperature.
See Table B.2 for the rank correlations with the minimum temperature.
See Table B.3 for the rank correlations with the maximum temperature.
See Table B.4 for the rank correlations with the amount of precipitation.
See Table B.5 for the rank correlations with the duration of precipitation.

On the right hand side of each table, under the column *PTravel distance*, the significance of the rank correlation between the weather variable and *Travel distance* is listed. Under the column *PProfessional travel* the significance of the rank correlation between the weather variable and *Professional travel* is listed. The same holds for *PNon-professional travel* which represents the significance of the rank correlation between the weather variable and *Non-professional travel*; *PNumber of casualties* for *Number of casualties* and *PNumber of fatalities* for *Number of fatalities* are related similarly. Rank correlations with a significance level of more than 0.01 (1%) are suppressed and marked with a dot in order to ease reading.

The factor α, as defined in *Section 4*, *Analysis of the effects of precipitation on road safety* is determined for a number of casualty types (*fatalities*; *hospitalised casualties*; *slight injury casualties*; *fatalities* plus *hospitalised casualties* and *all casualties*), for different periods (the whole period 1987-2006; the first period 1987-1996 and the last period 1997-2006) and the four meteorological seasons (spring after March 1, summer after June 1, autumn after September 1, and winter after December 1). For each combination of these, the casualties in travel mode *Pedestrian*; *Bicycle*; *Light moped*; *Moped*; *Motorcycle*; *Car*; *Van*; *Lorry* and *All* (the sum of all together) against a crash opponent of type *Object* (fixed object or single accident); *Pedestrian*; *Bicycle*; *Light moped*; *Moped*; *Motorcycle*; *Car*; *Van*; *Lorry*; *All* (any type of object). In each cell, the estimate of the factor α is listed, printed above its approximate 50% confidence region. Note that the confidence region is exact, given the assumed distribution, which is approximate, but reasonable. Asymmetry found in the confidence regions is most likely reflected in the accurate distributions. The appendix contains the following tables:

Table B.6: Fatalities, full period 1987-2006.
Table B.7: Hospitalised casualties, full period 1987-2006.
Table B.8: Slightly injured, full period 1987-2006.
Table B.9: Fatalities plus hospitalised, full period 1987-2006.
Table B.10: All casualties, full period 1987-2006.
Table B.11: All casualties, period 1987-1996.
Table B.12: All casualties, period 1997-2006.
Table B.13: All casualties, spring 1987-2006.
Table B.14: All casualties, summer 1987-2006.
Table B.15: All casualties, autumn 1987-2006.
Table B.16: All casualties, winter 1987-2006.
Table B.17: All casualties in crashes with cars, own traffic mode (vertical), full period 1987-2006.
Table B.18, Fatalities (all models), periods 1987-1996 and 1997-2006.

Transport mode	Dry/wet	Travel distance	Professional travel	Non-professional travel	Number of casualties	Number of fatalities	PTravel distance	PProfessional travel	PNon-professional travel	PNumber of casualties	PNumber of fatalities
All modes	<0.1 mm	0.06020	-0.03840	0.08631	0.22865	0.09409	<.0001	0.0006	<.0001	<.0001	<.0001
All modes	>= 0.1 mm	0.05192	.	0.04792	0.08803	.	<.0001	0.0795	<.0001	<.0001	0.4101
Walking	<0.1 mm	-0.10514	-0.03478	-0.09957	-0.05027	-0.05475	<.0001	0.0019	<.0001	<.0001	<.0001
Walking	>= 0.1 mm	-0.06152	.	-0.05867	-0.09668	-0.08483	<.0001	0.1060	<.0001	<.0001	<.0001
Bicycle	<0.1 mm	0.30522	0.07035	0.33279	0.23290	0.11332	<.0001	<.0001	<.0001	<.0001	<.0001
Bicycle	>= 0.1 mm	0.17700	0.06279	0.19024	0.07958	0.04335	<.0001	<.0001	<.0001	<.0001	0.0008
Moped	<0.1 mm	0.03029	.	0.03024	0.24057	0.11665	0.0073	0.1395	0.0080	<.0001	<.0001
Moped	>= 0.1 mm	.	.	.	0.15093	0.06563	0.0425	0.1603	0.1440	<.0001	<.0001
Motorcycle	<0.1 mm	0.17942	0.10617	0.16714	0.41409	0.18301	<.0001	<.0001	<.0001	<.0001	<.0001
Motorcycle	>= 0.1 mm	0.10780	0.07811	0.09534	0.29063	0.14807	<.0001	<.0001	<.0001	<.0001	<.0001
Car	<0.1 mm	.	-0.04731	0.06447	-0.03033	.	0.0181	<.0001	<.0001	0.0079	0.0809
Car	>= 0.1 mm	0.03182	.	0.03781	.	-0.03869	0.0038	0.0313	0.0006	0.0915	0.0014
Van	<0.1 mm	.	.	.	.	.	0.0843	0.3613	0.0121	0.8765	0.5371
Van	>= 0.1 mm	.	.	0.03561	.	.	0.0901	0.5353	0.0080	0.6408	0.4130
Public transport	<0.1 mm	-0.04784	-0.03013	-0.04649	.	.	<.0001	0.0074	<.0001	0.7542	0.6750
Public transport	>= 0.1 mm	.	.	-0.03878	.	.	0.0111	0.3927	0.0004	0.6375	0.8052

Table B.1 *Rank-correlations between the average temperature and the total travel distance, work- and non-work related travel distance according to OVG/MON, and the number of casualties (fatalities plus hospitalised) and fatalities, disaggregated into transport mode and dry and wet (>= 0.1 mm precipitation) weather conditions. The last five columns contain the respective significance levels.*

Transport mode	Dry/wet	Travel distance	Professional travel	Non-professional travel	Number of casualties	Number of fatalities	PTravel distance	PProfessional travel	PNon-professional travel	PNumber of casualties	PNumber of fatalities
All modes	<0.1 mm	0.04562	-0.04020	0.07376	0.17534	0.07435	<.0001	0.0003	<.0001	<.0001	<.0001
All modes	>= 0.1 mm	0.04347	.	0.04275	0.07832	.	<.0001	0.0686	0.0001	<.0001	0.4871
Walking	<0.1 mm	-0.11238	-0.03468	-0.10613	-0.05550	-0.03962	<.0001	0.0020	<.0001	<.0001	0.0030
Walking	>= 0.1 mm	-0.06828	.	-0.06518	-0.09202	-0.08240	<.0001	0.1068	<.0001	<.0001	<.0001
Bicycle	<0.1 mm	0.24783	0.05757	0.27101	0.17960	0.08897	<.0001	<.0001	<.0001	<.0001	<.0001
Bicycle	>= 0.1 mm	0.14399	0.05273	0.15305	0.06134	0.03564	<.0001	<.0001	<.0001	<.0001	0.0058
Moped	<0.1 mm	.	.	.	0.21138	0.10971	0.0130	0.1570	0.0304	<.0001	<.0001
Moped	>= 0.1 mm	.	.	.	0.13349	0.05713	0.0855	0.1752	0.2987	<.0001	<.0001
Motorcycle	<0.1 mm	0.15805	0.09140	0.14960	0.34062	0.15189	<.0001	<.0001	<.0001	<.0001	<.0001
Motorcycle	>= 0.1 mm	0.08804	0.06890	0.07264	0.24532	0.12561	<.0001	<.0001	<.0001	<.0001	<.0001
Car	<0.1 mm	.	-0.04896	0.05913	-0.03818	.	0.0735	<.0001	<.0001	0.0008	0.0291
Car	>= 0.1 mm	.	.	0.03506	.	-0.03187	0.0141	0.0290	0.0014	0.6068	0.0085
Van	<0.1 mm	.	.	.	.	.	0.1478	0.3991	0.0450	0.6675	0.9642
Van	>= 0.1 mm	.	.	0.03615	.	.	0.0346	0.3038	0.0071	0.5375	0.7919
Public transport	<0.1 mm	-0.04950	-0.03129	-0.04945	.	.	<.0001	0.0054	<.0001	0.9647	0.4697
Public transport	>= 0.1 mm	.	.	-0.03345	.	.	0.0210	0.3438	0.0024	0.8692	0.7865

Table B.2. *Rank-correlations between the minimum temperature and the total travel distance, work- and non-work related travel distance according to OVG/MON, and the number of casualties (fatalities plus hospitalised) and fatalities, disaggregated into transport mode and dry and wet (>= 0.1 mm precipitation) weather conditions. The last five columns contain the respective significance levels.*

Transport mode	Dry/wet	Travel distance	Professional travel	Non-professional travel	Number of casualties	Number of fatalities	PTravel distance	PProfessional travel	PNon-professional travel	PNumber of casualties	PNumber of fatalities
All modes	<0.1 mm	0.06820	-0.03383	0.09019	0.25538	0.10401	<.0001	0.0024	<.0001	<.0001	<.0001
All modes	>= 0.1 mm	0.05586	.	0.04978	0.09679	.	<.0001	0.0955	<.0001	<.0001	0.4621
Walking	<0.1 mm	-0.09435	-0.03291	-0.08912	-0.04032	-0.05645	<.0001	0.0033	<.0001	0.0007	<.0001
Walking	>= 0.1 mm	-0.05257	.	-0.04941	-0.09135	-0.07947	<.0001	0.1606	<.0001	<.0001	<.0001
Bicycle	<0.1 mm	0.32710	0.07555	0.35669	0.25938	0.12419	<.0001	<.0001	<.0001	<.0001	<.0001
Bicycle	>= 0.1 mm	0.19494	0.06465	0.21301	0.09115	0.04528	<.0001	<.0001	<.0001	<.0001	0.0005
Moped	<0.1 mm	0.03263	.	0.03485	0.25176	0.11830	0.0038	0.1506	0.0022	<.0001	<.0001
Moped	>= 0.1 mm	.	.	.	0.15968	0.06738	0.0283	0.2282	0.0557	<.0001	<.0001
Motorcycle	<0.1 mm	0.18247	0.10799	0.17009	0.43982	0.19384	<.0001	<.0001	<.0001	<.0001	<.0001
Motorcycle	>= 0.1 mm	0.11542	0.07748	0.10702	0.31384	0.15479	<.0001	<.0001	<.0001	<.0001	<.0001
Car	<0.1 mm	0.03087	-0.04230	0.06467	.	.	0.0055	0.0001	<.0001	0.0347	0.1498
Car	>= 0.1 mm	0.03290	.	0.03801	.	-0.04283	0.0028	0.0367	0.0006	0.0403	0.0004
Van	<0.1 mm	.	.	.	.	.	0.0898	0.3960	0.0119	0.5302	0.3726
Van	>= 0.1 mm	.	.	0.03606	.	.	0.1312	0.6694	0.0072	0.4501	0.1025
Public transport	<0.1 mm	-0.04347	.	-0.04203	.	.	<.0001	0.0127	0.0002	0.5369	0.8809
Public transport	>= 0.1 mm	.	.	-0.03943	.	.	0.0135	0.5499	0.0003	0.4572	0.8826

Table B.3. *Rank-correlations between the maximum temperature and the total travel distance, work- and non-work related travel distance according to OVG/MON, and the number of casualties (fatalities plus hospitalised) and fatalities, disaggregated into transport mode and dry and wet (>= 0.1 mm precipitation) weather conditions. The last five columns contain the respective significance levels.*

Transport mode	Dry/wet	Travel distance	Professional travel	Non-professional travel	Number of casualties	Number of fatalities	PTravel distance	PProfessional travel	PNon-professional travel	PNumber of casualties	PNumber of fatalities
All modes	>= 0.1 mm	.	.	.	0.07804	.	0.1466	0.9714	0.3461	<.0001	0.6756
Walking	>= 0.1 mm	-0.06880	.	-0.06829	.	.	<.0001	0.7529	<.0001	0.0670	0.3347
Bicycle	>= 0.1 mm	-0.10107	.	-0.11971	.	.	<.0001	0.0230	<.0001	0.8267	0.4196
Moped	>= 0.1 mm	.	.	.	.	.	0.7929	0.2962	0.4762	0.5346	0.1871
Motorcycle	>= 0.1 mm	-0.04126	.	-0.04604	-0.06864	.	0.0006	0.1949	0.0002	<.0001	0.5256
Car	>= 0.1 mm	.	.	.	0.11613	.	0.9270	0.8569	0.8107	<.0001	0.1517
Van	>= 0.1 mm	.	.	.	0.06951	.	0.8503	0.2844	0.0891	<.0001	0.9707
Public transport	>= 0.1 mm	.	.	.	.	.	0.5019	0.8643	0.4409	0.0283	0.1725

Table B.4. *Rank-correlations between the amount of precipitation and the total travel distance, work- and non-work related travel distance according to OVG/MON, and the number of casualties (fatalities plus hospitalised) and fatalities, disaggregated into transport mode and dry and wet (>= 0.1 mm precipitation) weather conditions. The last five columns contain the respective significance levels.*

Transport mode	Dry/wet	Travel distance	Professional travel	Non-professional casualties	Number of casualties	Number of fatalities	PTravel distance	PProfessional travel	PNon-professional travel	PNumber of casualties	PNumber of fatalities
All modes	>= 0.1 mm	.	.	.	0.04385	.	0.0309	0.8505	0.1830	<.0001	0.6931
Walking	>= 0.1 mm	-0.04748	.	-0.04707	0.03084	.	<.0001	0.6096	<.0001	0.0090	0.0708
Bicycle	>= 0.1 mm	-0.14764	-0.04925	-0.16529	.	.	<.0001	<.0001	<.0001	0.0208	0.0442
Moped	>= 0.1 mm	.	.	.	-0.04261	.	0.3524	0.9842	0.1620	0.0002	0.0214
Motorcycle	>= 0.1 mm	-0.04088	.	-0.05527	-0.13920	-0.04916	0.0007	0.3718	<.0001	<.0001	0.0002
Car	>= 0.1 mm	.	.	.	0.12184	0.03412	0.7865	0.6275	0.8523	<.0001	0.0050
Van	>= 0.1 mm	.	.	.	0.06888	.	0.1063	0.0433	0.9976	<.0001	0.6630
Public transport	>= 0.1 mm	.	.	.	.	.	0.2717	0.7739	0.1060	0.2864	0.3286

Table B.5. *Rank-correlations between the duration of precipitation and the total travel distance, work- and non-work related travel distance according to OVG/MON, and the number of casualties (fatalities plus hospitalised) and fatalities, disaggregated into travel mode and dry and wet (>= 0.1 mm precipitation) weather conditions. The last five columns contain the respective significance levels.*

All fatalities 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	23.82 (5.70,107.10)	.	.	0.79 (0.10,1.81)	.	1.64 (1.41,1.89)	0.34 (0.03,0.73)	0.38 (0.07,0.75)	1.13 (0.98,1.29)
Bicycle	.	.	1.04 (0.20,2.33)	.	.	3.16 (1.49,5.85)	0.65 (0.52,0.80)	1.37 (0.97,1.83)	0.44 (0.24,0.66)	0.68 (0.58,0.79)
Light moped	.	.	.	.	.	.	1.24 (0.63,2.04)	1.53 (0.18,4.17)	.	0.78 (0.40,1.26)
Moped	1.12 (0.69,1.64)	.	-0.67 (-0.91,-0.10)	.	.	.	.	1.31 (0.61,2.27)	0.46 (0.10,0.91)	0.38 (0.23,0.53)
Motorcycle	.	.	.	.	.	.	0.28 (0.05,0.56)	.	-0.57 (-0.76,-0.26)	.
Car	1.00 (0.90,1.10)	.	.	.	.	.	1.15 (1.01,1.30)	0.98 (0.72,1.29)	0.75 (0.59,0.93)	0.95 (0.88,1.02)
Van	1.75 (1.29,2.29)	.	.	.	.	.	1.11 (0.51,1.91)	1.68 (0.59,3.43)	1.68 (1.02,2.54)	1.48 (1.17,1.82)
Lorry	0.47 (0.01,1.10)	.	.	.	.	.	.	.	0.68 (0.03,1.68)	0.34 (0.02,0.74)
All	0.94 (0.86,1.03)	1.46 (0.16,3.85)	.	.	.	0.88 (0.37,1.56)	0.96 (0.88,1.05)	0.95 (0.78,1.14)	0.59 (0.48,0.70)	0.84 (0.79,0.88)

Table B.6. *Factor α and 50% confidence regions for fatalities disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, entire period 1987-2006.*

All hospitalized 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	41.87 (15.90,107.30)	0.37 (0.17,0.60)	.	0.67 (0.52,0.83)	0.57 (0.25,0.96)	1.01 (0.94,1.07)	0.75 (0.58,0.94)	0.45 (0.18,0.76)	0.87 (0.82,0.93)
Bicycle	0.52 (0.41,0.64)	-0.42 (-0.57,-0.23)	0.59 (0.48,0.70)	0.68 (0.25,1.21)	0.69 (0.59,0.80)	0.60 (0.37,0.87)	1.21 (1.16,1.26)	1.12 (0.99,1.25)	0.27 (0.15,0.40)	0.98 (0.94,1.01)
Light moped	0.51 (0.33,0.72)	-0.60 (-0.83,-0.16)	0.61 (0.24,1.08)	-0.51 (-0.76,-0.09)	.	.	0.67 (0.53,0.81)	1.01 (0.62,1.47)	1.67 (0.83,2.83)	0.59 (0.50,0.69)
Moped	0.79 (0.71,0.87)	0.68 (0.37,1.03)	1.05 (0.86,1.26)	0.82 (0.27,1.56)	0.75 (0.61,0.90)	.	0.82 (0.77,0.87)	0.84 (0.71,0.97)	1.21 (0.98,1.45)	0.84 (0.80,0.87)
Motorcycle	0.35 (0.25,0.45)	.	.	.	.	.	0.42 (0.34,0.50)	0.25 (0.07,0.46)	0.89 (0.50,1.37)	0.39 (0.33,0.44)
Car	1.32 (1.27,1.36)	0.73 (0.15,1.55)	0.84 (0.43,1.34)	.	0.59 (0.23,1.04)	.	1.46 (1.42,1.50)	1.31 (1.21,1.41)	1.40 (1.30,1.51)	1.39 (1.36,1.42)
Van	1.74 (1.58,1.91)	.	2.63 (0.82,5.89)	.	1.78 (0.46,4.16)	.	1.16 (1.02,1.31)	2.15 (1.76,2.60)	1.15 (0.89,1.45)	1.50 (1.40,1.60)
Lorry	1.45 (1.14,1.81)	.	.	.	.	.	0.70 (0.34,1.14)	2.18 (1.05,3.87)	1.28 (0.92,1.69)	1.26 (1.06,1.48)
All	1.14 (1.11,1.17)	0.20 (0.05,0.37)	0.68 (0.60,0.76)	0.35 (0.11,0.62)	0.67 (0.60,0.75)	0.38 (0.24,0.53)	1.16 (1.13,1.18)	1.11 (1.05,1.17)	1.11 (1.04,1.18)	1.10 (1.08,1.12)

Table B.7. *Factor α and 50% confidence regions for hospitalized casualties disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, entire period 1987-2006.*

All Minor injuries 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	1.43 (0.16,3.68)	0.26 (0.15,0.39)	0.52 (0.21,0.89)	0.68 (0.59,0.77)	0.36 (0.12,0.63)	0.78 (0.74,0.83)	0.50 (0.38,0.63)	.	0.66 (0.63,0.70)
Bicycle	0.50 (0.44,0.57)	.	0.22 (0.17,0.27)	.	0.44 (0.39,0.49)	0.14 (0.01,0.28)	1.24 (1.21,1.27)	1.04 (0.97,1.12)	1.07 (0.93,1.21)	0.96 (0.94,0.98)
Light moped	0.70 (0.57,0.85)	.	.	.	0.23 (0.04,0.44)	0.92 (0.13,2.13)	0.67 (0.60,0.74)	0.54 (0.36,0.74)	.	0.58 (0.53,0.63)
Moped	1.23 (1.17,1.29)	0.87 (0.74,1.02)	0.75 (0.68,0.82)	0.29 (0.07,0.55)	0.58 (0.51,0.65)	.	0.89 (0.87,0.92)	0.78 (0.71,0.85)	1.02 (0.87,1.18)	0.90 (0.88,0.92)
Motorcycle	0.91 (0.82,1.01)	.	.	1.09 (0.17,2.58)	-0.31 (-0.49,-0.09)	.	0.61 (0.56,0.67)	0.99 (0.80,1.21)	.	0.64 (0.60,0.69)
Car	1.90 (1.86,1.94)	1.31 (0.92,1.76)	1.15 (0.96,1.36)	0.60 (0.22,1.08)	0.74 (0.58,0.91)	0.50 (0.31,0.71)	1.82 (1.80,1.85)	1.83 (1.77,1.90)	1.69 (1.61,1.77)	1.80 (1.79,1.82)
Van	2.19 (2.05,2.33)	.	0.81 (0.33,1.43)	8.27 (1.98,25.83)	1.52 (0.92,2.29)	0.51 (0.00,1.21)	1.55 (1.47,1.64)	1.67 (1.48,1.87)	1.56 (1.36,1.79)	1.72 (1.66,1.78)
Lorry	1.70 (1.48,1.95)	.	-0.69 (-0.92,-0.18)	.	.	.	1.28 (1.03,1.56)	0.42 (0.10,0.83)	0.90 (0.70,1.12)	1.19 (1.07,1.31)
All	1.57 (1.54,1.60)	0.53 (0.45,0.62)	0.46 (0.42,0.50)	0.31 (0.19,0.43)	0.51 (0.48,0.55)	0.24 (0.15,0.32)	1.36 (1.34,1.37)	1.34 (1.30,1.37)	1.36 (1.31,1.42)	1.28 (1.27,1.29)

Table B.8. *Factor α and 50% confidence regions for slightly injured disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, entire period 1987-2006.*

All killed + hospitalized 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	35.29 (15.72,78.75)	0.39 (0.19,0.62)	.	0.67 (0.53,0.83)	0.57 (0.27,0.92)	1.07 (1.01,1.13)	0.69 (0.53,0.85)	0.42 (0.21,0.65)	0.90 (0.86,0.95)
Bicycle	0.51 (0.40,0.62)	-0.43 (-0.58,-0.25)	0.59 (0.49,0.71)	0.57 (0.18,1.08)	0.68 (0.57,0.78)	0.73 (0.49,1.00)	1.17 (1.12,1.22)	1.14 (1.02,1.27)	0.32 (0.21,0.43)	0.95 (0.92,0.99)
Light moped	0.49 (0.31,0.69)	-0.60 (-0.83,-0.16)	0.60 (0.22,1.06)	-0.51 (-0.76,-0.09)	.	.	0.70 (0.57,0.84)	1.04 (0.66,1.49)	1.08 (0.51,1.84)	0.60 (0.51,0.70)
Moped	0.80 (0.72,0.88)	0.67 (0.37,1.02)	1.00 (0.82,1.21)	0.80 (0.25,1.53)	0.74 (0.61,0.89)	.	0.80 (0.75,0.85)	0.85 (0.73,0.99)	1.09 (0.89,1.30)	0.82 (0.78,0.85)
Motorcycle	0.33 (0.24,0.42)	.	.	.	.	.	0.40 (0.33,0.48)	0.21 (0.04,0.41)	0.41 (0.14,0.74)	0.36 (0.31,0.41)
Car	1.27 (1.23,1.31)	0.69 (0.13,1.48)	0.76 (0.37,1.23)	.	0.56 (0.21,1.00)	.	1.44 (1.40,1.48)	1.28 (1.19,1.37)	1.27 (1.18,1.36)	1.34 (1.32,1.37)
Van	1.74 (1.59,1.91)	.	2.63 (0.82,5.89)	.	1.78 (0.46,4.16)	.	1.16 (1.02,1.31)	2.12 (1.74,2.54)	1.23 (0.99,1.51)	1.50 (1.40,1.59)
Lorry	1.29 (1.01,1.60)	.	.	.	.	.	0.65 (0.32,1.06)	1.83 (0.84,3.29)	1.20 (0.88,1.57)	1.13 (0.95,1.32)
All	1.12 (1.09,1.15)	0.23 (0.07,0.40)	0.67 (0.59,0.75)	0.27 (0.05,0.52)	0.66 (0.59,0.74)	0.42 (0.28,0.57)	1.14 (1.12,1.17)	1.10 (1.04,1.16)	0.99 (0.93,1.06)	1.08 (1.06,1.09)

Table B.9. *Factor α and 50% confidence regions for fatalities plus hospitalized casualties disaggregated vertically into the casualties' own transport mode and disaggregated horizontally into the transport mode of the casualties' crash opponent, entire period 1987-2006*.

All casualties 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	-0.72 (-0.93,-0.08)	5.68 (3.07,9.76)	0.30 (0.19,0.40)	0.33 (0.08,0.63)	0.68 (0.60,0.76)	0.44 (0.25,0.66)	0.89 (0.86,0.93)	0.58 (0.48,0.68)	0.26 (0.11,0.41)	0.75 (0.72,0.78)
Bicycle	0.50 (0.45,0.56)	.	0.30 (0.26,0.35)	0.23 (0.08,0.40)	0.48 (0.44,0.53)	0.32 (0.20,0.45)	1.22 (1.20,1.24)	1.07 (1.01,1.14)	0.69 (0.61,0.78)	0.96 (0.94,0.97)
Light moped	0.64 (0.52,0.75)	.	0.19 (0.06,0.35)	.	0.19 (0.04,0.37)	0.72 (0.10,1.60)	0.68 (0.61,0.74)	0.66 (0.49,0.84)	0.35 (0.07,0.69)	0.58 (0.54,0.63)
Moped	1.10 (1.05,1.15)	0.85 (0.72,0.98)	0.79 (0.72,0.85)	0.38 (0.17,0.62)	0.62 (0.55,0.68)	.	0.87 (0.85,0.90)	0.80 (0.74,0.86)	1.05 (0.92,1.17)	0.88 (0.86,0.90)
Motorcycle	0.67 (0.60,0.74)	.	0.16 (0.02,0.32)	1.01 (0.19,2.26)	-0.27 (-0.43,-0.07)	.	0.54 (0.50,0.59)	0.68 (0.54,0.82)	0.26 (0.08,0.47)	0.54 (0.51,0.58)
Car	1.63 (1.60,1.66)	1.18 (0.84,1.57)	1.10 (0.93,1.29)	0.59 (0.23,1.04)	0.71 (0.57,0.87)	0.42 (0.26,0.61)	1.73 (1.71,1.76)	1.69 (1.64,1.74)	1.53 (1.47,1.59)	1.67 (1.65,1.68)
Van	2.02 (1.91,2.12)	.	1.01 (0.52,1.64)	8.27 (1.98,25.83)	1.56 (0.99,2.27)	.	1.46 (1.39,1.54)	1.77 (1.60,1.95)	1.44 (1.28,1.62)	1.66 (1.60,1.71)
Lorry	1.57 (1.39,1.76)	.	.	.	.	.	1.12 (0.92,1.35)	0.68 (0.35,1.08)	0.99 (0.82,1.17)	1.17 (1.07,1.28)
All	1.39 (1.37,1.41)	0.48 (0.41,0.56)	0.50 (0.47,0.53)	0.30 (0.20,0.41)	0.55 (0.52,0.58)	0.29 (0.22,0.36)	1.30 (1.29,1.32)	1.27 (1.24,1.30)	1.21 (1.17,1.26)	1.22 (1.21,1.23)

Table B.10. *Factor α and 50% confidence regions for all casualties disaggregated vertically into the casualties' own transport mode and disaggregated horizontally into the transport mode of the casualties' crash opponent, entire period 1987-2006.*

All casualties 1987-1996	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	3.87 (0.18,15.64)	0.21 (0.09,0.35)	.	0.76 (0.66,0.87)	0.24 (0.03,0.47)	0.85 (0.80,0.89)	0.64 (0.51,0.78)	0.41 (0.21,0.63)	0.73 (0.69,0.77)
Bicycle	0.47 (0.41,0.55)	-0.21 (-0.33,-0.07)	0.24 (0.17,0.30)	.	0.44 (0.39,0.50)	0.30 (0.15,0.46)	1.21 (1.18,1.25)	1.07 (0.98,1.17)	0.84 (0.72,0.96)	0.94 (0.92,0.97)
Light moped	0.54 (0.38,0.72)	.	.	.	0.32 (0.06,0.62)	2.03 (0.76,4.03)	0.56 (0.46,0.65)	0.25 (0.03,0.51)	.	0.46 (0.40,0.53)
Moped	1.04 (0.97,1.10)	1.09 (0.91,1.29)	0.85 (0.76,0.95)	0.42 (0.08,0.84)	0.57 (0.49,0.66)	.	0.85 (0.82,0.88)	0.86 (0.77,0.95)	1.02 (0.88,1.18)	0.87 (0.85,0.89)
Motorcycle	0.65 (0.56,0.75)	.	0.28 (0.08,0.52)	2.57 (0.83,5.62)	.	.	0.39 (0.33,0.44)	0.80 (0.58,1.04)	0.58 (0.29,0.92)	0.47 (0.43,0.51)
Car	1.71 (1.67,1.75)	2.14 (1.46,2.98)	1.30 (0.99,1.65)	.	0.62 (0.40,0.87)	0.41 (0.18,0.67)	1.73 (1.70,1.76)	1.67 (1.59,1.75)	1.69 (1.60,1.78)	1.70 (1.68,1.72)
Van	2.09 (1.94,2.25)	.	1.82 (0.45,4.15)	.	0.68 (0.00,1.73)	.	1.38 (1.28,1.49)	1.88 (1.60,2.18)	1.82 (1.55,2.13)	1.68 (1.60,1.76)
Lorry	2.07 (1.79,2.38)	.	.	.	.	.	1.30 (0.99,1.66)	0.55 (0.12,1.12)	1.11 (0.86,1.39)	1.44 (1.28,1.60)
All	1.42 (1.39,1.45)	0.56 (0.45,0.67)	0.47 (0.43,0.52)	.	0.53 (0.49,0.57)	0.27 (0.18,0.37)	1.26 (1.24,1.28)	1.24 (1.19,1.28)	1.35 (1.29,1.41)	1.20 (1.19,1.22)

Table B.11. *Factor α and 50% confidence regions for all casualties disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, entire period 1987-1996.*

All casualties 1997-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	6.07 (3.14,10.81)	0.41 (0.25,0.59)	0.68 (0.29,1.17)	0.56 (0.45,0.68)	0.90 (0.51,1.37)	0.97 (0.91,1.03)	0.50 (0.37,0.65)	.	0.78 (0.74,0.83)
Bicycle	0.55 (0.45,0.64)	.	0.38 (0.31,0.45)	0.48 (0.26,0.73)	0.53 (0.47,0.60)	0.36 (0.17,0.57)	1.23 (1.19,1.27)	1.07 (0.98,1.17)	0.49 (0.37,0.62)	0.97 (0.95,1.00)
Light moped	0.70 (0.55,0.86)	.	0.36 (0.17,0.57)	.	.	.	0.76 (0.68,0.85)	0.90 (0.67,1.16)	0.56 (0.18,1.05)	0.67 (0.61,0.74)
Moped	1.16 (1.09,1.24)	0.53 (0.37,0.72)	0.71 (0.62,0.81)	0.35 (0.10,0.66)	0.68 (0.58,0.79)	-0.36 (-0.56,-0.09)	0.91 (0.88,0.95)	0.74 (0.65,0.83)	1.09 (0.88,1.32)	0.90 (0.87,0.93)
Motorcycle	0.69 (0.60,0.79)	.	.	.	-0.41 (-0.61,-0.14)	.	0.75 (0.68,0.83)	0.59 (0.42,0.78)	.	0.63 (0.58,0.68)
Car	1.55 (1.51,1.59)	0.61 (0.28,1.02)	1.00 (0.79,1.22)	0.82 (0.36,1.41)	0.77 (0.59,0.98)	0.44 (0.20,0.70)	1.74 (1.71,1.77)	1.70 (1.63,1.77)	1.36 (1.28,1.45)	1.64 (1.62,1.66)
Van	1.95 (1.81,2.09)	.	0.88 (0.38,1.53)	.	1.96 (1.22,2.92)	.	1.53 (1.43,1.64)	1.71 (1.50,1.94)	1.18 (0.99,1.39)	1.63 (1.56,1.70)
Lorry	1.07 (0.86,1.30)	.	.	.	.	.	0.96 (0.69,1.26)	0.80 (0.34,1.40)	0.87 (0.64,1.13)	0.92 (0.80,1.06)
All	1.36 (1.33,1.39)	0.39 (0.29,0.50)	0.52 (0.48,0.57)	0.46 (0.32,0.61)	0.57 (0.52,0.61)	0.31 (0.20,0.43)	1.36 (1.34,1.38)	1.30 (1.25,1.34)	1.07 (1.01,1.13)	1.24 (1.23,1.26)

Table B.12. *Factor α and 50% confidence regions for all casualties disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, entire period 1997-2006.*

All casualties springtimes 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	.	.	.	.	.	0.28 (0.22,0.34)	0.32 (0.16,0.50)	.	0.20 (0.16,0.24)
Bicycle	0.13 (0.03,0.22)	-0.36 (-0.51,-0.17)	.	-0.37 (-0.56,-0.13)	.	.	0.78 (0.74,0.82)	0.69 (0.57,0.81)	.	0.52 (0.49,0.55)
Light moped	0.21 (0.03,0.41)	.	-0.56 (-0.70,-0.38)	.	.	.	0.40 (0.29,0.52)	0.61 (0.29,0.99)	1.02 (0.26,2.18)	0.29 (0.21,0.37)
Moped	0.62 (0.53,0.71)	.	0.17 (0.07,0.28)	.	0.13 (0.02,0.25)	.	0.56 (0.52,0.61)	0.44 (0.33,0.55)	0.59 (0.39,0.83)	0.50 (0.47,0.53)
Motorcycle	0.27 (0.16,0.38)	.	.	.	.	.	0.18 (0.11,0.26)	0.48 (0.25,0.74)	-0.49 (-0.68,-0.22)	0.20 (0.15,0.26)
Car	1.35 (1.30,1.41)	.	0.65 (0.35,1.00)	-0.74 (-0.93,-0.33)	.	.	1.36 (1.33,1.40)	1.42 (1.33,1.53)	1.10 (1.00,1.22)	1.33 (1.30,1.36)
Van	1.73 (1.53,1.94)	.	1.99 (0.81,3.84)	.	.	.	1.00 (0.88,1.14)	1.69 (1.36,2.06)	1.31 (1.00,1.67)	1.32 (1.22,1.42)
Lorry	0.92 (0.64,1.25)	.	.	.	5.63 (1.36,16.91)	.	0.95 (0.54,1.46)	.	0.35 (0.09,0.67)	0.66 (0.50,0.85)
All	1.04 (1.00,1.08)	-0.16 (-0.26,-0.04)	.	-0.22 (-0.37,-0.05)	0.06 (0.01,0.11)	.	0.91 (0.89,0.93)	0.97 (0.92,1.03)	0.74 (0.67,0.81)	0.83 (0.82,0.85)

Table B.13. *Factor α and 50% confidence regions for all casualties disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, springtimes 1987-2006.*

All casualties summers 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	.	.	.	0.16 (0.02,0.30)	0.38 (0.04,0.82)	0.38 (0.31,0.45)	0.31 (0.12,0.53)	0.54 (0.21,0.95)	0.28 (0.23,0.33)
Bicycle	0.20 (0.11,0.30)	-0.32 (-0.48,-0.14)	.	.	0.11 (0.04,0.19)	-0.21 (-0.36,-0.05)	0.77 (0.72,0.82)	0.64 (0.52,0.77)	0.83 (0.63,1.04)	0.52 (0.49,0.56)
Light moped	0.36 (0.17,0.58)	.	.	0.69 (0.14,1.46)	.	.	0.35 (0.24,0.47)	0.70 (0.36,1.11)	-0.62 (-0.81,-0.32)	0.29 (0.21,0.38)
Moped	0.68 (0.59,0.76)	0.34 (0.13,0.58)	0.38 (0.26,0.50)	.	-0.12 (-0.20,-0.02)	-0.55 (-0.75,-0.26)	0.61 (0.57,0.65)	0.66 (0.53,0.79)	0.76 (0.54,1.02)	0.55 (0.52,0.58)
Motorcycle	0.50 (0.40,0.62)	.	.	.	-0.87 (-0.96,-0.69)	-0.36 (-0.54,-0.13)	0.18 (0.11,0.26)	.	0.47 (0.12,0.92)	0.23 (0.18,0.29)
Car	1.49 (1.43,1.55)	0.94 (0.32,1.80)	0.45 (0.17,0.80)	.	0.47 (0.22,0.76)	.	1.63 (1.59,1.67)	1.72 (1.61,1.84)	1.86 (1.72,2.02)	1.58 (1.55,1.61)
Van	1.76 (1.56,1.97)	.	3.33 (1.27,6.86)	.	1.07 (0.08,2.73)	.	1.42 (1.27,1.58)	2.69 (2.22,3.22)	1.29 (0.98,1.64)	1.60 (1.49,1.71)
Lorry	1.70 (1.31,2.14)	.	.	.	.	.	1.33 (0.90,1.84)	1.65 (0.62,3.17)	1.68 (1.23,2.21)	1.42 (1.19,1.66)
All	1.12 (1.08,1.17)	.	0.10 (0.04,0.16)	.	0.06 (0.01,0.11)	-0.16 (-0.25,-0.05)	1.03 (1.01,1.05)	1.16 (1.10,1.23)	1.40 (1.31,1.50)	0.95 (0.94,0.97)

Table B.14. *Factor α and 50% confidence regions for all casualties disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, summers 1987-2006.*

All casualties autumns 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	.	0.42 (0.22,0.65)	1.16 (0.54,1.97)	0.90 (0.76,1.06)	.	1.24 (1.16,1.32)	0.72 (0.54,0.93)	.	1.03 (0.97,1.09)
Bicycle	0.73 (0.62,0.86)	0.22 (0.01,0.47)	0.51 (0.42,0.61)	0.45 (0.17,0.80)	0.71 (0.63,0.79)	0.93 (0.64,1.26)	1.44 (1.39,1.48)	1.31 (1.18,1.45)	0.99 (0.82,1.18)	1.18 (1.15,1.21)
Light moped	0.98 (0.75,1.22)	.	0.66 (0.37,1.00)	.	.	.	0.88 (0.76,1.01)	0.43 (0.17,0.72)	1.41 (0.70,2.39)	0.78 (0.69,0.87)
Moped	1.65 (1.55,1.76)	1.30 (1.04,1.58)	1.08 (0.96,1.21)	0.51 (0.15,0.95)	1.16 (1.03,1.30)	.	1.11 (1.07,1.16)	0.90 (0.79,1.01)	1.42 (1.19,1.68)	1.18 (1.15,1.22)
Motorcycle	1.11 (0.95,1.28)	.	.	.	.	0.50 (0.04,1.10)	0.94 (0.84,1.04)	1.00 (0.72,1.32)	0.81 (0.41,1.31)	0.92 (0.84,0.99)
Car	1.75 (1.69,1.81)	1.18 (0.63,1.89)	1.53 (1.18,1.94)	.	0.98 (0.69,1.30)	1.04 (0.64,1.53)	1.99 (1.94,2.03)	1.97 (1.87,2.07)	1.65 (1.54,1.76)	1.89 (1.86,1.92)
Van	2.20 (1.99,2.42)	.	1.90 (0.79,3.65)	.	1.04 (0.34,2.06)	.	1.82 (1.67,1.97)	1.59 (1.31,1.91)	2.10 (1.73,2.51)	1.90 (1.80,2.01)
Lorry	1.70 (1.35,2.09)	.	.	.	.	.	0.96 (0.63,1.34)	1.15 (0.44,2.14)	0.85 (0.57,1.17)	1.21 (1.03,1.40)
All	1.61 (1.57,1.66)	0.81 (0.65,0.97)	0.77 (0.71,0.84)	0.50 (0.31,0.72)	0.84 (0.78,0.90)	0.61 (0.45,0.78)	1.55 (1.53,1.57)	1.45 (1.39,1.51)	1.43 (1.35,1.51)	1.45 (1.44,1.47)

Table B.15. *Factor α and 50% confidence regions for all casualties disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, autumns 1987-2006.*

All casualties winters 1987-2006	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
Pedestrian	.	14.63 (7.87,26.42)	1.14 (0.84,1.48)	.	1.45 (1.25,1.68)	1.82 (1.17,2.64)	1.42 (1.34,1.50)	0.82 (0.63,1.04)	0.75 (0.40,1.17)	1.30 (1.24,1.37)
Bicycle	1.08 (0.93,1.25)	.	1.04 (0.88,1.21)	1.36 (0.83,2.01)	1.05 (0.93,1.17)	1.37 (0.89,1.95)	1.72 (1.66,1.77)	1.47 (1.33,1.62)	0.86 (0.68,1.06)	1.52 (1.48,1.56)
Light moped	1.04 (0.75,1.37)	.	0.93 (0.51,1.46)	.	0.68 (0.20,1.31)	6.16 (2.49,13.17)	1.09 (0.93,1.26)	1.12 (0.68,1.66)	.	1.02 (0.90,1.14)
Moped	1.34 (1.22,1.46)	1.69 (1.36,2.08)	1.47 (1.29,1.67)	1.29 (0.57,2.29)	1.14 (0.98,1.32)	.	1.15 (1.10,1.20)	1.18 (1.03,1.34)	1.25 (0.98,1.56)	1.22 (1.18,1.26)
Motorcycle	1.25 (1.02,1.51)	0.97 (0.30,1.95)	1.30 (0.72,2.06)	12.47 (4.87,30.74)	.	2.01 (0.77,4.01)	1.22 (1.07,1.38)	1.76 (1.27,2.35)	.	1.22 (1.11,1.34)
Car	1.88 (1.82,1.93)	2.49 (1.62,3.64)	1.48 (1.12,1.89)	2.69 (1.34,4.82)	1.81 (1.36,2.34)	0.91 (0.46,1.49)	1.90 (1.86,1.94)	1.59 (1.49,1.69)	1.52 (1.40,1.64)	1.82 (1.79,1.85)
Van	2.27 (2.07,2.48)	.	-0.78 (-0.94,-0.45)	.	5.18 (2.88,8.85)	4.65 (1.60,11.54)	1.55 (1.41,1.70)	1.43 (1.13,1.75)	1.08 (0.81,1.38)	1.74 (1.64,1.84)
Lorry	1.92 (1.56,2.33)	.	.	.	.	.	1.31 (0.87,1.85)	.	1.21 (0.86,1.62)	1.40 (1.19,1.62)
All	1.75 (1.70,1.79)	1.19 (0.98,1.41)	1.23 (1.12,1.33)	1.09 (0.78,1.45)	1.17 (1.09,1.26)	1.39 (1.10,1.71)	1.64 (1.62,1.67)	1.43 (1.36,1.49)	1.25 (1.16,1.33)	1.58 (1.56,1.60)

Table B.16. *Factor α and 50% confidence regions for all casualties' disaggregated vertically into the casualties' own transport mode disaggregated horizontally into the transport mode of the casualties' crash opponent, winters 1987-2006.*

Crashes with cars 1987-2006	Number of fatalities	Number of hospitalised	Number of slightly injured	Number of killed or hospitalised	Number of slightly or worse injured
Pedestrian	1.64 (1.41,1.89)	1.01 (0.94,1.07)	0.78 (0.74,0.83)	1.07 (1.01,1.13)	0.89 (0.86,0.93)
Bicycle	0.65 (0.52,0.80)	1.21 (1.16,1.26)	1.24 (1.21,1.27)	1.17 (1.12,1.22)	1.22 (1.20,1.24)
Light moped	1.24 (0.63,2.04)	0.67 (0.53,0.81)	0.67 (0.60,0.74)	0.70 (0.57,0.84)	0.68 (0.61,0.74)
Moped	.	0.82 (0.77,0.87)	0.89 (0.87,0.92)	0.80 (0.75,0.85)	0.87 (0.85,0.90)
Motorcycle	0.28 (0.05,0.56)	0.42 (0.34,0.50)	0.61 (0.56,0.67)	0.40 (0.33,0.48)	0.54 (0.50,0.59)
Car	1.15 (1.01,1.30)	1.46 (1.42,1.50)	1.82 (1.80,1.85)	1.44 (1.40,1.48)	1.73 (1.71,1.76)
Van	1.11 (0.51,1.91)	1.16 (1.02,1.31)	1.55 (1.47,1.64)	1.16 (1.02,1.31)	1.46 (1.39,1.54)
Lorry	.	0.70 (0.34,1.14)	1.28 (1.03,1.56)	0.65 (0.32,1.06)	1.12 (0.92,1.35)
All	0.96 (0.88,1.05)	1.16 (1.13,1.18)	1.36 (1.34,1.37)	1.14 (1.12,1.17)	1.30 (1.29,1.32)

Table B.17. *Factor α and 50% confidence regions for all casualties in crashes with cars, own transport mode (vertical) and count of casualties (horizontal), entire period 1987-2006.*

Fatalities (All tranport modes)	Object	Pedestrian	Bicycle	Light moped	Moped	Motorcycle	Car	Van	Lorry	All
1987-1996	1.21 (1.08,1.35)	n.s.	n.s.	n.s.	0.49 (0.02,1.13)	0.76 (0.17,1.58)	1.14 (1.03,1.25)	1.02 (0.79,1.29)	0.67 (0.52,0.82)	1.00 (0.93,1.07)
1997-2006	0.67 (0.56,0.79)	2.44 (0.31,7.11)	n.s.	n.s.	n.s.	1.12 (0.24,2.48)	0.70 (0.58,0.82)	0.86 (0.61,1.14)	0.48 (0.33,0.66)	0.63 (0.57,0.70)

Table B.18. *Factor α and 50% confidence regions for all fatalities (all models) disaggregated horizontally into the transport mode of the casualties' crash party, periods 1987-1996 and 1997-2006.*